NEPTUNE-ODYSSEY: Mission to Neptune-Triton System

"Neptune's moons were normal until Triton came crashing in."
New Scientist

Abigail Rymer and Noam Izenberg
+ Large team with Co-Is and collaborators from 17 national and international institutions including Kathy Mandt, Vikki Meadows and Tom Spilker attending this meeting.

“There is only one planet-type left to orbit – an Ice Giant, and we propose that NASA continue their voyage of excellence in planetary exploration and leadership by scheduling a Flagship-class mission to the Neptune-Triton system.”

[Rymer et al., 2019 PMCS proposal]

A flagship should be more than just an excellent mission for science.
It should inspire and excite the nation.

Support for Ice Giant Mission

‘Top and only priority for a new flagship mission is the Uranus Orbiter and Probe.’

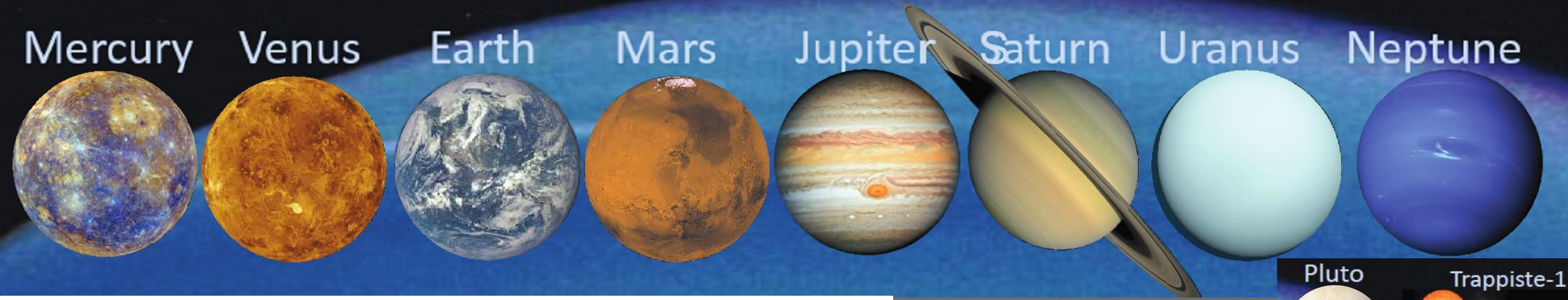
[Vision and Voyages for Planetary Science in the Decade 2013-2022]

This changes in the coming decade and the Outer Planets Assessment Group (OPAG) support **Neptune** for a flagship mission.

‘…owing to Triton, a captured dwarf planet itself and also a high priority Ocean World target’

[OPAG Scientific Goals for Exploration of the Outer Solar System]

‘It Takes a Village.’ Collaborative Outer Planet Missions.



WHITE PAPER FOR THE
HELIOPHYSICS SCIENCE DECADAL SURVEY, 2013-2023.

The Case for Exploring Uranus’ Magnetosphere.

This White Paper is endorsed by 66 scientists (listed at the end) from the USA and Europ
of whom are early career scientists representing the driving force of the heliophysics con
in the decades to come.

WHITE PAPER FOR EXOPLANET SCIENCE STRATEGY 2018

Solar System Ice Giants: Exoplanets in our Backyard.

(Cover page)

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Advancing Space Science Requires NASA Support for Coordination Between the Science Mission Directorate Communities

White paper submitted as a State of the Profession paper to the Astro2020 Decadal Survey. It will be submitted next to the Planetary and Heliophysics Decadal Surveys.

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Using the Interstellar Probe to Decipher Exoplanet Signatures of Our Planets from the Very Local Interstellar Medium

Pontus C. Brandt, Ralph McNutt, Michael Paul, Carey Lisse, Kathleen Mandt, Abigail Rymer

VISION *and* VOYAGES

for Planetary Science in the Decade 2013-2022

TABLE ES.3 Large-Class Missions (in priority order)

Mission Recommendation	Science Objectives	Key Challenges	Decision Rules	Chapter
Mars Astrobiology Explorer-Cacher descope	• Perform in situ science on Mars samples to look for evidence of ancient life or chemistry document, and package samples for future collection and return to Earth	• Keeping within Mars Science Laboratory design constraints • Sample handling, encapsulation, and containerization • Increased rover traverse speed over Mars Science Laboratory and Mars Exploration Rover	Should be flown only if it can be conducted for a cost to NASA of no more than approximately $2.5 billion (FY2015 dollars)	6
Jupiter Europa Orbiter descope	Explore Europa to investigate its habitability	• Radiation • Mass • Power • Instruments	Should be flown only if changes to both the mission design and the NASA planetary budget make it affordable without eliminating any other recommended missions	8
Uranus Orbiter and Probe (no solar-electric propulsion stage)	• Investigate the interior structure, atmosphere, and composition of Uranus ... us satellite	• Demanding entry probe mission • Long life (15.4 years) for orbiter • High magnetic cleanliness for orbiter • System mass and power	Should be initiated even if both MAX-C and JEO take place	7

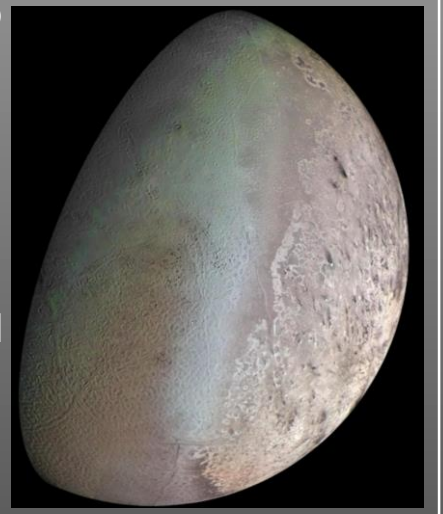
=MARS 2020

=Europa Clipper

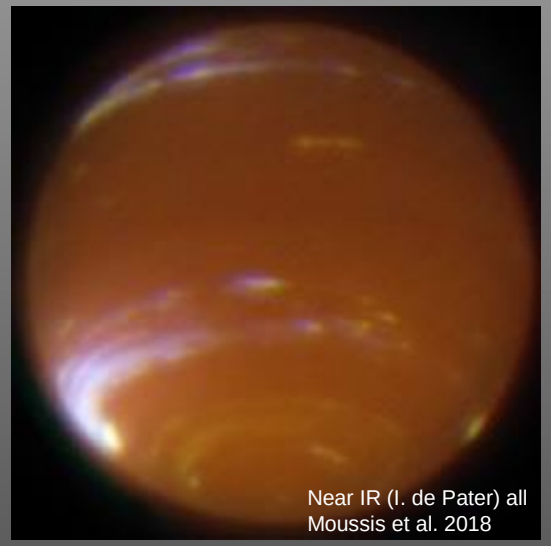
=Neptune-Triton?

ODYSSEY: Mission to Neptune-Triton System

- Ice Giant Orbiter and Probe mission: In Top 3 Decadal Priorities
- Comparative planetology of Kuiper Belt Dwarf Planets (Triton)
    - Ocean Worlds, heliophysics, and exoplanet objectives
    - "Neptune's moons were normal until Triton came crashing in." (New Scientist)
- Neptune > Uranus due to captured dwarf planet Triton



- Structure and characteristics of the dynamo and overall interior.
- Bulk composition (V&V; IG predecadal study report 2017)
- Dwarf planet comparative planetology (Simon et al. 2018 WP)



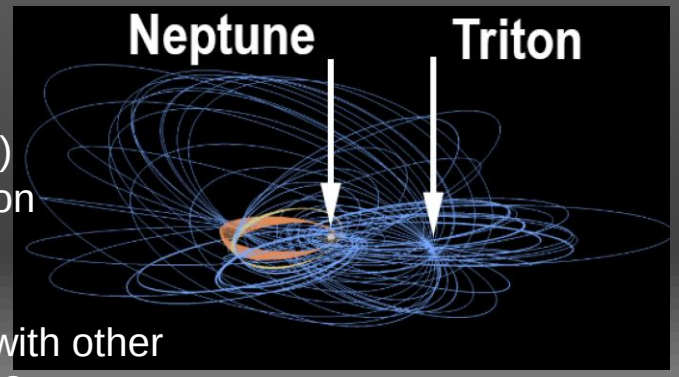
Required Measurements:

- Magnetic field
- Gravitational harmonics
- Spectroscopy
- Visible imager
- Ions and electrons
- Neutral mass spectrometry
- Dust

Candidate Architectures: **Cassini-Huygens, New Horizons, Juno, LCross**

Development

- Cost/technical evaluation
- Cassini-like tour, using Triton
- Long-lived RPS (eMMRTGs?)
- Atmospheric thermal protection
- Engage ESA, NASA/Helio
- Optical Comm?
- **Flagship Class**. Cost share with other agencies and NASA divisions?



Why this proposal?

At least 7 Ice Giant mission proposals (of 54 total) were submitted to NASA's Planetary Mission Concept Study (PMCS) call:

"Given the high science priority of the Ice Giants, a number of studies have been performed of dedicated orbital missions. However, previous NASA-led studies have lacked a strong Triton element." Rymer PMCS proposal.

'Neptune-Triton Mission: a flagship for everyone' Carol Paty, OPAG 2019.

Working groups

38 total
17 women, including PI and 3/8 Working Group leads also early career Project Scientist Kirby Runyon.
Also include Princeton sociologist Janet Vertesi

	Neptune	Aurora/Magnetosphere/ Solar Wind	Icy sats and rings	Triton	Exoplanets
Co-Lead	Mark Hofstadter	Ian Cohen	Tracy Becker	Alan Stern	Jonathan Fortney
Co-Lead	Krista Soderlund	Frank Crary		Lynnae Quick	
	Jonathan Fortney	Corey Cochrane	Noam Izenberg	Frank Crary	Leigh Fletcher
	Corey Cochrane	Elena Provornikova	Imke de Pater	Noam Izenberg	Alan Stern
	Imke de Pater	Adam Masters	Kirby Runyon	Corey Cochrane	Noam Izenberg
	Kunio Sayanagi	Krista Soderlund	Zibi Turtle	Kirby Runyon	Lynnae Quick
	Leigh Fletcher	George Hospodarsky	James Roberts	Candy Hansen	Kathy Mandt
	Adam Masters	H. Todd Smith	Matt Hedman	Kathy Mandt	Ian Cohen
	Kathy Mandt			Zibi Turtle	Kevin Stevenson
	Amy Simon			James Roberts	
				H. Todd Smith	

PMCS review Major Strengths

- A flagship for everyone
  - *"multi-disciplinary and would impact virtually the entire planetary science community"*
- New approach the gives equal weight to system science, especially Triton.
  - *"explore Triton as an ocean world…and leverage recent advances understanding KBOs, dwarf planets and the prevalence of ice giants among exoplanets"*
- Great team
- Robust approach
- Professional approach to addresses human challenges is given as much weight as engineering challenges
  - *"thoughtful strategies to address leadership, inclusive membership and turnover"*

‘This study will provide a practical ‘shovel ready’ concept that is quickly executable in the coming decade.’

[Rymer et al., 2019 PMCS proposal]

Minor Weaknesses

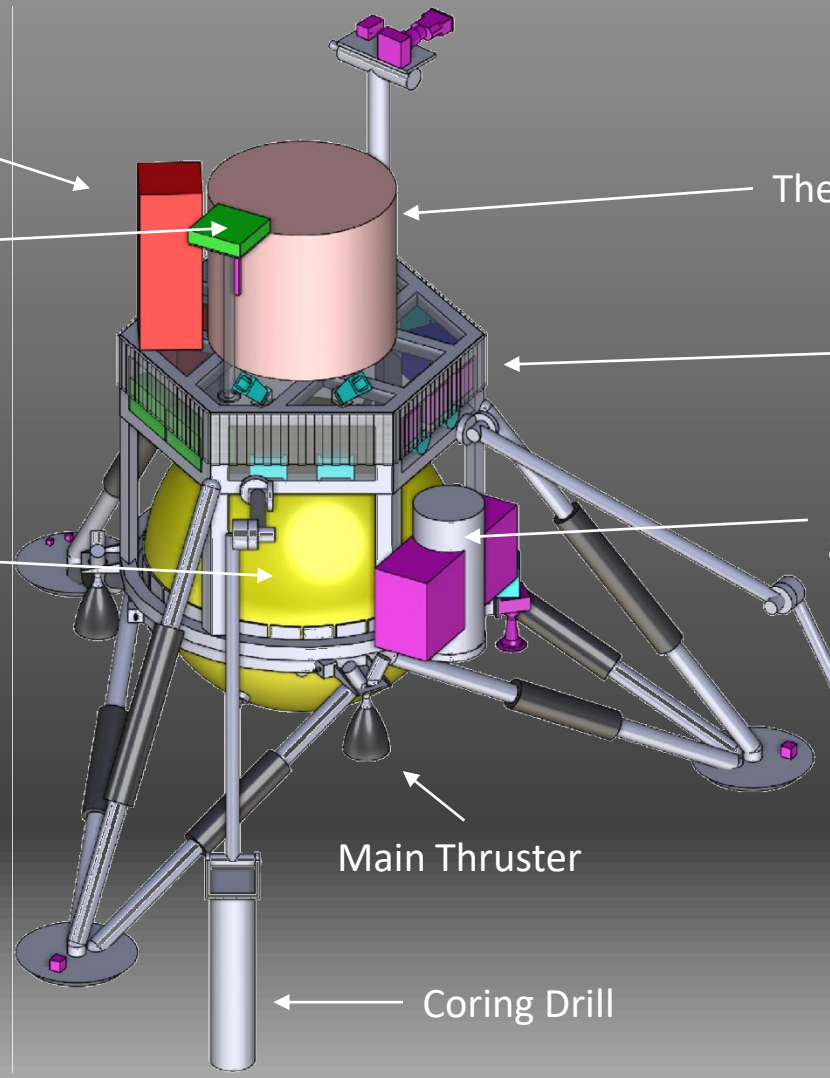
- We can’t be ready by 2030, can we?
- Should not have ditched the Triton trade study. Encouraged to analyze the risk/return of a Landed element as part of the study

This is my favorite ‘weakness’. We were reluctant to lose the Triton in situ measurement and this enables us to reintroduce it.

NIAC Triton Hopper

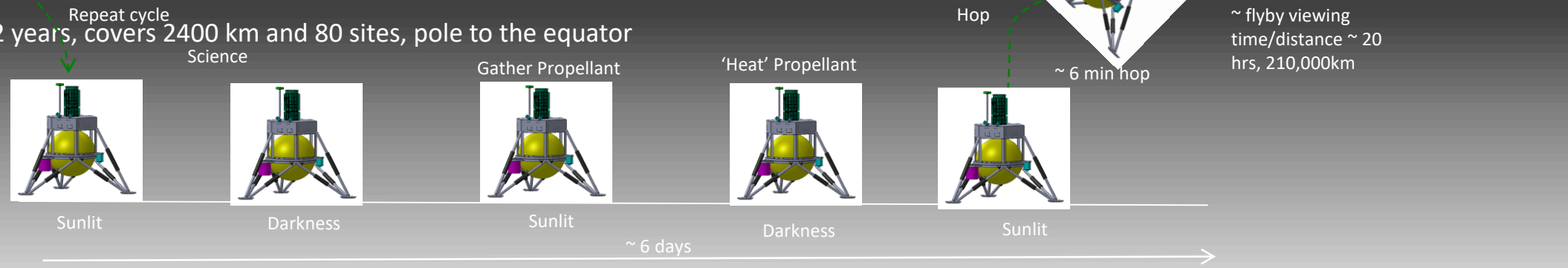
Subsystem Components:

- **Communications**
- **GN&C**
- **C&DH**
- **Science**
- **Thermal Block**
- **Electrical Power**
- **Propellant Tank**
- **Structures**

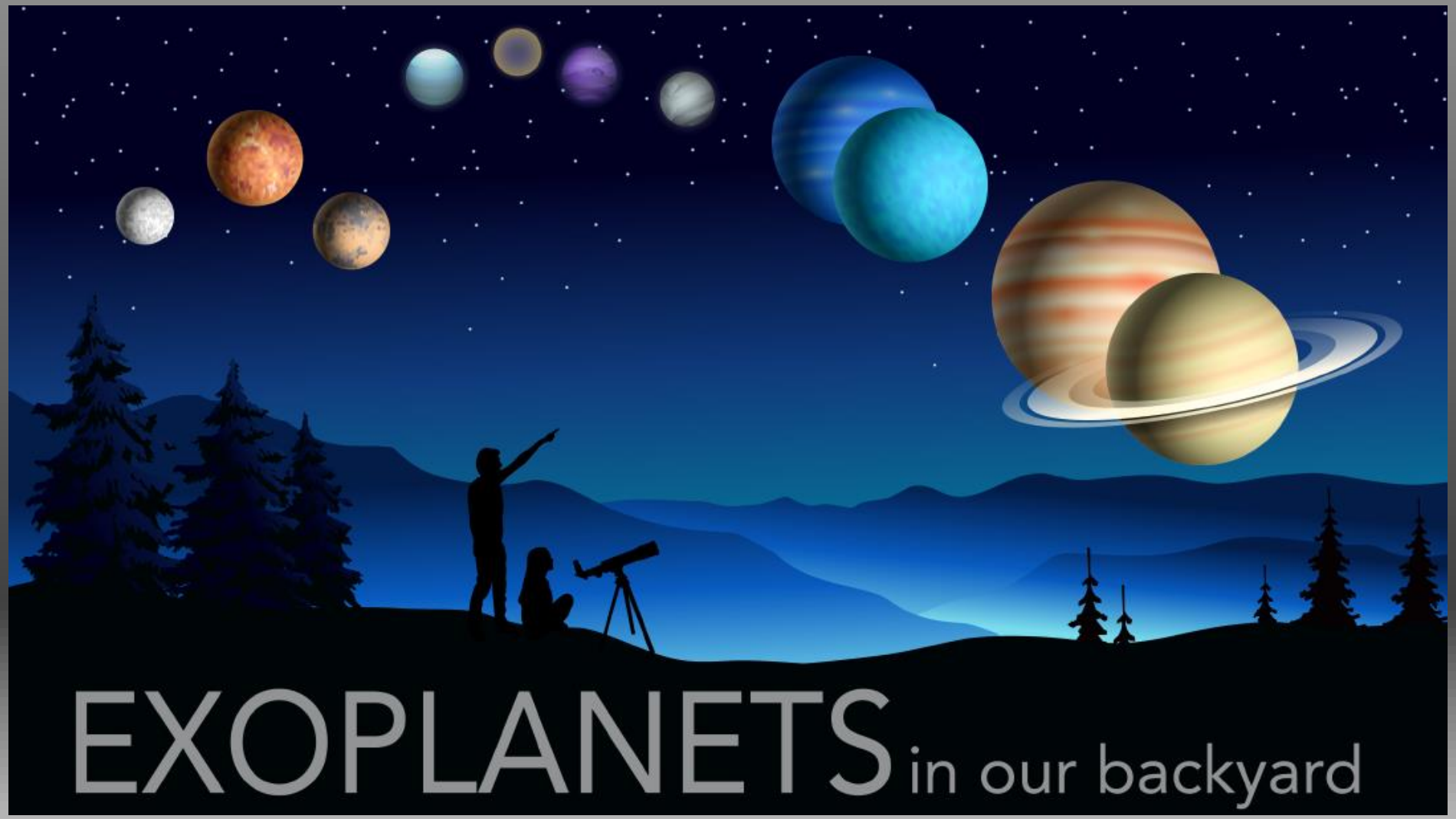


Strawman Surface Conops

- Triton: 141 hr (~6 earth days) rotation, tidally locked, Checkout (2 weeks)
- Hop up the Neptune side – gives you some light from Neptune for science imaging the terrain
- Hop period – every 6 days
- Science scan continuously (3 days light, 3 days darkness – but with Neptune shine), instruments take turns as needed.
- Gather N2 propellant (3 days – sunlit)
    - Baseline: pump from atmosphere using turbopump and freezing N2 on inside of tank
        - Shorts tank to surface using high conducting path (removed during heating)
- Heat Propellant/ tank (3 days darkness)
- Propulsion Hop Flight take off/land at dawn: Uo to 80 km horizontal, x km high, Sample atmosphere during hop, Sample geysers during hop, Hop during Neptune Orbiter flyby
- Landing: soft landing using LIDAR
- Communicate with orbiter every 2.5 hours (100 km) for 10? Minutes. (at 500 km orbit period is 3.7 hrs)
    - communicate during hops
    - Science data ~ 1000 Mb/day, 6 Gb of data from 6 days,
- Repeat cycle for 2 years, covers 2400 km and 80 sites, pole to the equator



Exoplanets – a rear view camera to explore the ‘exoplanets on our own back yard.



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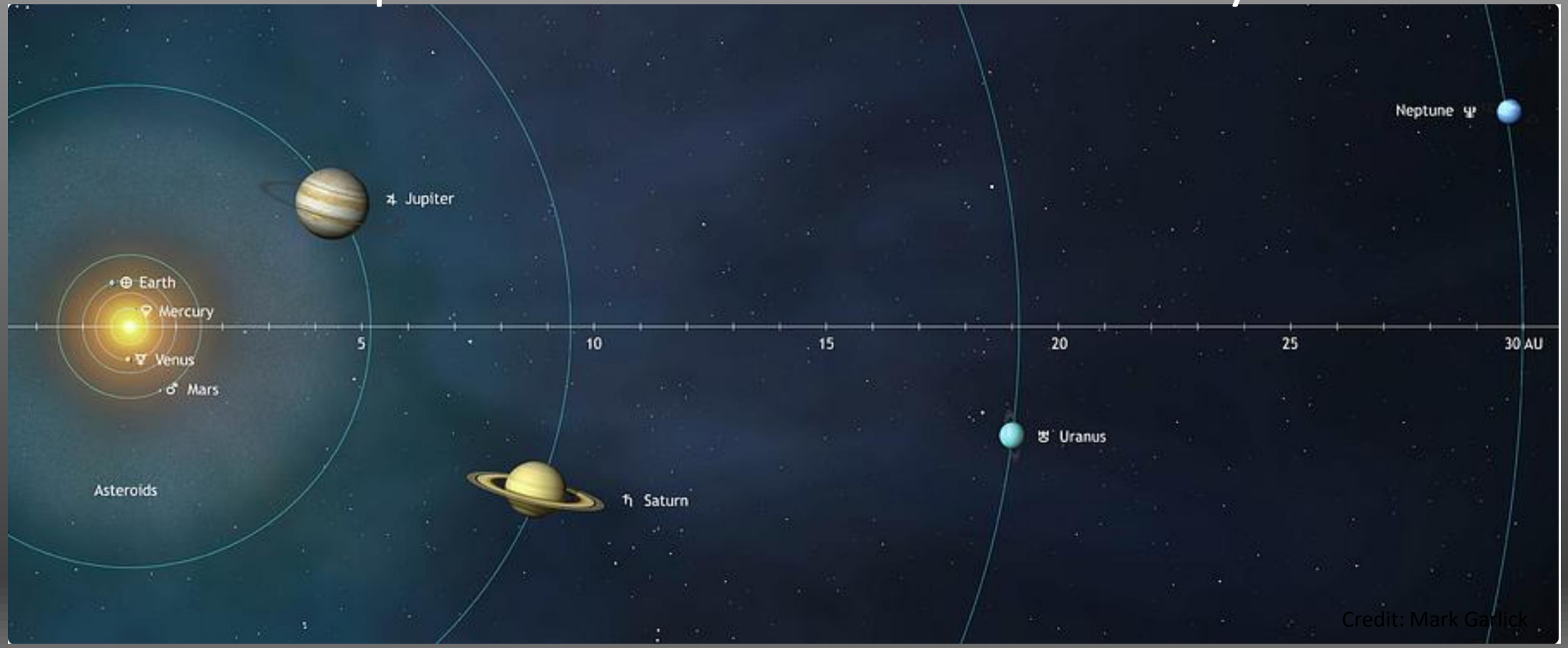

Outreach

- Website in prep, www.NeptuneOdyssey.jhuapl.edu
- Presentation
  - OPAG 4 Feb 2020
  - Exoplanets in our Backyard 7 Feb 2020
  - LPSC, Sunday 15 March 2020

Key milestones

- Bi-weekly full team telecons (all recorded)
  - Tom Spilker: ‘Aerocapture’
  - Noam Izenberg: ‘Triton Hopper’
  - Mark Hofstadter: ‘Trajectory’
  - Ralph McNutt: ‘Power’
  - Dana Hurley: ‘L-cross mission design’
  - (next time) Amy Simon: ‘If Ice Giant formation is difficult then why are they so common?’
- ~Weekly WG telecoms
- WG deliver STMs by Feb 7
- In person meeting at APL 25-27 March 2020
- Design Lab at APL 4-9 May 2020
- Report due to NASA 30 June 2020

Summary and Musings

- Focus on ‘system science’ and I am hearing that echoing back to us a lot, I think we have really captured the zeitgeist of planetary science with this mission target and concept and approach.
- NASA’s selection of *this* Ice Giants PMCS shows that satellite science is a driving consideration in ice giant exploration.
- New Horizons’ exploration of Pluto, Charon and Arrokoth captures the imagination for Kuiper belt science and a Triton-centric Neptune tour is an excellent opportunity to enhance the science from the New Horizons mission
- Provide an unashamedly large flagship mission that excites the broader community and the nation.
- Worried about the late start. We’d be worried even without the late start! But excited to have the chance to do this and the science team and broader support have been fantastic.